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POLLUTION ESTIMATION FACTORS

Construction Engineering Research
Lab. (Army), Champaign, Illinois

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TECHNICAL REPORT N-12
November 1976
Characterization of Wastes From Army Installations

POLLUTION ESTIMATION FACTORS

by
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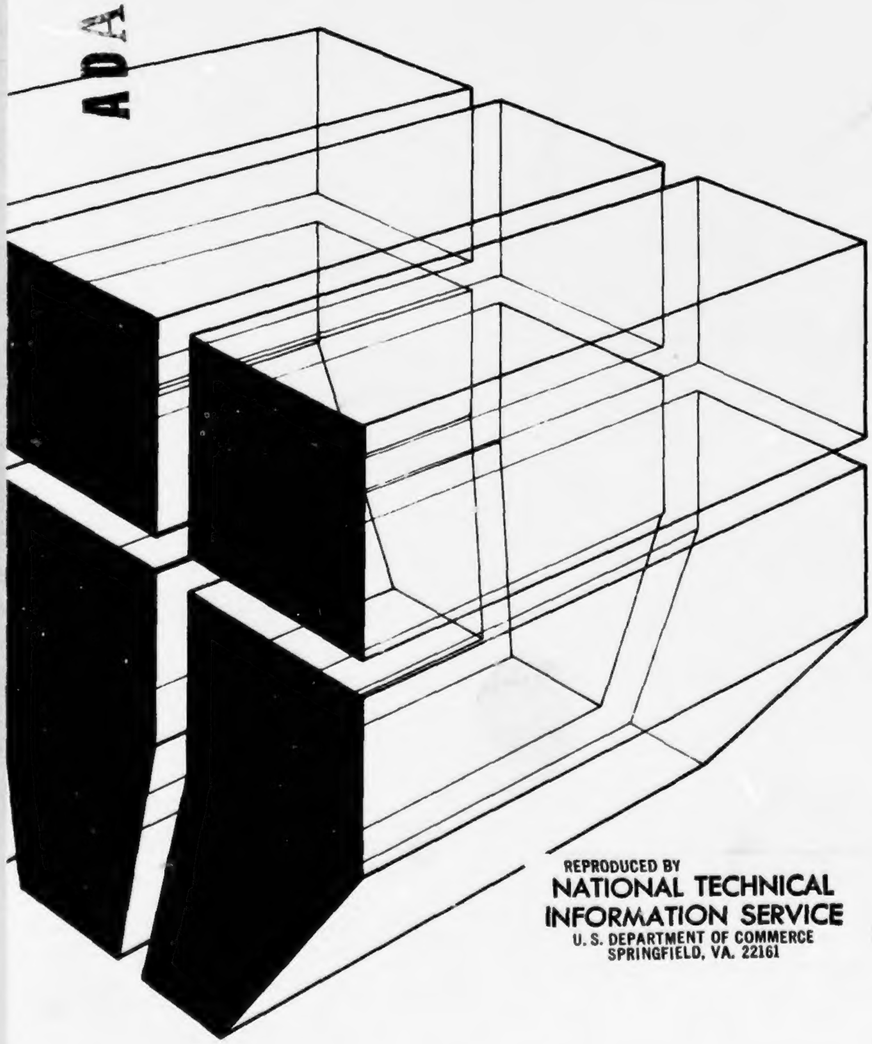

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This report contains emission factors for estimating pollution resulting from military facility and vehicle operations. The air pollution emission factors are from the U.S. Environmental Protection Agency's (USEPA) AP-42 *Compilation of Air Pollutant Emission Factors* and its supplements. Wastewater and solid waste emission factors were developed from data recorded in the literature. Future research will validate the Army relevancy of these literature-based factors.

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FOREWORD

The U.S. Army Construction Engineering Research Laboratory (CERL) conducted this study for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A162121A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task 01, "Environmental Quality Management for Military Facilities"; Work Unit 004, "Characterization of Wastes From Army Installations." The QCR number is 1.03-006(3). V. Gottschalk was the OCE Technical Monitor.

This study was performed by the Environmental Engineering Team (ENE), Environmental Division (EN), CERL. B. A. Donahue was the CERL Principal Investigator, and G. W. Schanche was the Associate Investigator. Valuable contributions were made by Barbara Byrne, Kathleen Poskus, and Byong Shin. Administrative support and counsel provided by Dr. R. K. Jain, Chief of EN, and Mr. W. J. Mikucki, Acting Chief of ENE, is gratefully acknowledged.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Deputy Director.

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POLLUTION ESTIMATION FACTORS

1 INTRODUCTION

Background

AR 200-1[1] requires the Army to evaluate the environmental consequences of proposed actions while they are being planned. For a highly controversial or an environmentally significant action, the regulation additionally requires preparation of an environmental impact statement which details the impacts of the action. To effectively perform these tasks, Army planning personnel must have some means of predicting the amount and types of impacts likely to result from a particular action.

In most cases, an interdisciplinary team of experts is required to adequately assess the environmental consequences of a proposed activity. However, for air pollution, the U.S. Environmental Protection Agency (USEPA) has developed a series of emission factors that relate pollutant quantities resulting from fuel combustion and industrial operations to the level of that particular polluting activity. This report extends the emission factor approach to allow estimation of types and amounts of solid waste and wastewater discharged from certain activities common to U.S. Army Training and Doctrine Command (TRADOC) and Forces Command (FORSCOM) military facility operation.

Purpose

The purpose of this report is to provide factors for estimating the amounts of air pollutants, water pollutants, and solid waste materials generated by the operation of military facilities and vehicles.

Approach

This document identifies pollutant-generating activities resulting from the operation of military facilities and vehicles, and when possible, develops pollutant estimation factors.

The report consists of three parts based on the class of pollutants being estimated. Chapter 2 contains examples of how to use air pollutant emission factors and identifies Army-relevant portions of *Compilation of Air Pollutant Emission Factors.*[2] Chapter 3 contains factors for estimating solid waste composition and quantity. Chapter 4 contains factors for estimating wastewater composition and quantity. Estimation factors contained in Chapters 3 and 4 are based on data from the literature.

Noise pollution emission estimation techniques are not included in this report because of the lack of existing data and the complexity of predicting noise pressure levels resulting from Army activities. The U.S. Army Construction Engineering Research Laboratory (CERL) has been developing noise prediction techniques for blast (impulse noise), rotary-wing aircraft, and other noise sources at Army installations. Two types of models are currently under development. The first model predicts the noise intensity as a function of receptor distance, source characteristics, and meteorological conditions. The second model predicts the community, or receptor, response resulting from certain noise intensity levels. As a result of this research effort, Army personnel will be able to address noise impact resulting from Army military activities. Several CERL technical reports provide additional information regarding the research effort in the noise area.[3,4]

An emission factor is basically the average amount of pollutant discharged per level of a specific activity. To estimate the amount of pollution resulting from an activity, it is only necessary to multiply the emission factor by the activity level. Specific examples showing how to apply these factors are supplied at the beginning of each chapter.

Use of the Report

The information contained in this report can be used by Army personnel to assess the environmental consequences of actions involving facility operations. The emission factor approach should be used only when a rough estimate of the pollutant discharge resulting from a particular activity is required. For example, emissions estimates can be used in several

[1] *Environmental Protection and Enhancement*, AR 200-1 (Department of the Army, December 1973).

[2] *Compilation of Air Pollutant Emission Factors*, AP-42, 2nd ed. and Supplements 1 through 6 (U.S. Environmental Protection Agency [USEPA], April 1973).

[3] B. Homans, J. McBryan, and P. Schomer, *User Manual for the Acquisition and Evaluation of Operational Blast Noise Data*, Technical Report E-42/AD782911 (U.S. Army Construction Engineering Research Laboratory [CERL], June 1974).

[4] P. D. Schomer, *Predicting Community Response to Blast Noise*, Technical Report E-17/AD773690 (CERL, December 1973).

ways. In compiling inventories of the installation's pollution sources, emission estimates are useful for determining the relative significance of each identified waste source. In planning a survey of a specific waste source, emission estimates can be used to select the appropriate sampling equipment and analytical techniques. Emission estimates can also be used to help determine the environmental impact of a proposed change in facility operation. Additionally, emission estimates can be used to select appropriate hardware and management systems in the preliminary design of pollution control systems. Finally, emission estimates can be used to identify waste sources which are in potential violation of environmental regulations.

When the need for accurate data arises, such as in the final design of a pollution control facility, emission factor estimates cannot be substituted for actual study of the specific problem-fostering situation. Since these emission factors were developed from a broad base of similar civilian activities, emissions estimates derived by using these factors may or may not accurately reflect the specific pollutant discharge characteristics resulting from a particular activity at a specific installation. Thus, the factors contained herein should be used with caution. Future work will field-validate these factors and modify them for Army use.

2 AIR POLLUTANT EMISSION FACTORS

Army-Relevant Portions of Compilation of Air Pollutant Emission Factors

The USEPA's *Compilation of Air Pollutant Emission Factors* (AP-42) contains the most complete compilation of air pollution emission factors. Army-relevant sections of AP-42 have not been reproduced in this report because of their length. It is strongly recommended that every installation maintain a current copy of AP-42 and its supplements.*

The Army-relevant sections of AP-42 are:

1. External Combustion Sources
   - 1.1 Bituminous Coal Combustion
   - 1.2 Anthracite Coal Combustion
   - 1.3 Fuel Oil Combustion
   - 1.4 Natural Gas Combustion
   - 1.5 Liquified Petroleum Gas Combustion
   - 1.6 Wood Waste Combustion in Boilers
   - 1.7 Lignite Combustion

2. Solid Waste Disposal
   - 2.1 Refuse Incineration
   - 2.4 Open Burning
   - 2.5 Sewage Sludge Incineration

3. Internal Combustion Engine Sources
   - 3.1 Highway Vehicles
   - 3.2 Off-Highway, Mobile Sources
   - 3.3 Off-Highway, Stationary Sources

4. Evaporation Loss Sources
   - 4.1 Dry Cleaning
   - 4.2 Surface Coating
   - 4.3 Petroleum Storage
   - 4.4 Gasoline Marketing

8. Mineral Products Industry
   - 8.1 Asphaltic Concrete Plants
   - 8.9 Coal Cleaning
   - 8.10 Concrete Batching
   - 8.19 Sand and Gravel Processing
   - 8.20 Stone Quarrying and Processing

11. Miscellaneous Sources
    - 11.1 Forest Wildfires
    - 11.2 Fugitive Dust Sources

Appendix A. Miscellaneous Data
Appendix D. Projected Emission Factors for Highway Vehicles

*Copies of AP-42 and supplements can be obtained from:

1. National Technical Information Service (NTIS)
   5285 Port Royal Road
   Springfield, VA 22161

   AP-42, order PB 223 996
   Supplement 1, order PB 231 170
   Supplement 2, order PB 235 735
   Supplement 3, order PB 235 736
   Supplement 4, order N75-22940
   Supplement 5, order PB 249 526
   Supplement 6, order PB 254 274

2. Superintendent of Documents
   U.S. Government Printing Office (USGPO)
   Washington, DC 20402

   AP-42/Supplements 1-4, *Compilation of Air Pollutant Emission Factors*, 2nd Edition. EP 4.9: 42/2/Rep.
   Supplement 5, EP 4.9: 42/2/Supp. 5

The External Combustion Source category contains all processes which burn coal, oil, or gas for power production or heat. The Solid Waste Disposal category consists of incinerators and open-burning activities. The Internal Combustion Engine category consists of all sources using gasoline, diesel, or liquified petroleum gas (LPG) fuel power plants. The Evaporation Loss category consists of dry cleaning, surface coating, and gasoline marketing and storage activities. The Mineral Products category consists of concrete, asphalt, coal, sand, and gravel processing activities. The Miscellaneous Source category contains factors for forest and brush burning and for sources of wind-blown dust.

The emission factors in AP-42 are not precise indicators of air emissions from a specific source, but are useful for providing preliminary estimates of air emissions from a group of activities without conducting field investigations. To better illustrate the use of these air pollutant emission factors, several examples for point sources, line sources, and area sources are provided.

Point Source Example

Problem

Calculate the emissions from a 50-million Btu/hr (52-million kJ/hr) input spreader stoker furnace at the main steam generating plant. The furnace burns bituminous coal with a 10 percent ash content and a 2 percent sulfur content. The furnace is equipped with a low-resistance cyclone to control flyash emissions. The furnace consumes an average of 1.25 tons of coal/hr (1.134 MT/hr).

Solution

Using Table 1.1-2 of AP-42, "Emission Factors for Bituminous Coal Combustion Without Control Equipment," refer to the entries under 10 to 100 × 10^6 Btu/hr heat input—spreader stoker.

Particulates = 13A lb/ton (6.5 kg/MT) coal
(where A = 10)
= 13(10) = 130 lb/ton (65 kg/MT)
coal burned.

However, the furnace is equipped with a low-resistance cyclone to control flyash emissions. Based on Table 1.1-1, "Range of Collection Efficiencies for Common Types of Flyash Control Equipment," particulates are reduced between 70 and 80 percent.

Therefore, between 26 and 39 lb/ton of particulates of coal burned (13 and 19.5 kg/MT) are released to the atmosphere. The average emission rate is between 32.5 and 48.75 lb/hr (14.74 to 22.11 kg/hr).

Sulfur oxides = 38S (where S = 2 percent)
= 38(2) = 76 lb/ton (38 kg/MT) coal
burned for an average emission
rate of 95 lb/hr (43.1 kg/hr).

Carbon monoxide = 2 lb/ton (1 kg/MT) coal
burned for an average
emission of 2.5 lb/hr
(1.13 kg/hr).

Hydrocarbons (as CH_4) = 1 lb/ton (0.5 kg/MT)
coal burned or
1.25 lb/hr (0.57 kg/hr)
average.

Nitrogen oxides = 15 lb/ton (7.5 kg/MT) coal
burned or 18.75 lb/hr
(8.5 kg/hr) average.

Aldehydes = 0.005 lb/ton (0.0025 kg/MT) coal
burned or 0.00625 lb/hr
(0.00284 kg/hr) average.

Line Source Example

Problem

Estimate the carbon monoxide emissions resulting from daily rush periods on a 4-mi (6.4 km) section of I-675 running through the northwest corner of the installation. During the average rush period, 2500

cars pass through this section at an average speed of 40 mph (64 km/hr). Use 1975 as the base year and assume (1) the average temperature is 65°F (18°C), (2) it is a low altitude location, (3) 5 percent of the vehicles are in cold start operation and 0.25 percent in hot start operation, and (4) vehicle composition is:

Pre-1968	5 percent	1972	20 percent
1968	10 percent	1973	15 percent
1969	10 percent	1974	10 percent
1970	10 percent	1975	5 percent
1971	15 percent		

Solution

Using the Federal Test Procedure (FTP) method for determining automobile emissions defined in AP-42, calculate the composite exhaust emission factor for carbon monoxide according to:

$$e_{co} = \sum_{i=1963}^{1975} C_i M_i V_i Z_i r_i$$

where e_{co} = composite emission factor for carbon monoxide given in grams/mile
C_i = FTP mean emission factor for carbon monoxide for i^{th} model year
M_i = fraction of miles traveled by i^{th} model year
V_i = speed correction factor for carbon monoxide in i^{th} model year
Z_i = temperature correction factor for carbon monoxide in i^{th} model year
r_i = hot/cold vehicle operation factor for carbon monoxide in i^{th} model year.

The total number of vehicle miles traveled in the 4-mi (6.4 km) section during the daily rush period is:

(2500 vehicles)(4 mi/vehicle) = 10,000 vehicle mi (16 000 km).

The values for calculating the composite emission factor for carbon monoxide, e_{co}, are listed in Table 1.

Using the values in Table 1, the composite emission factor, e_{co}, is calculated to be

$$e_{co} = \sum_{i=1963}^{1975} e_{ico} = 21.87 \text{ g/mi } (13.67 \text{ g/km})$$

Table 1

Values for Calculating e_{co}

Model Year	C_i*	M_i**	V_i†	Z_i††	r_i‡	e_{ico}‡‡	CO_i# (kg)
Pre-1968	96.0	0.05	0.58	1.12	0.77	2.40	24.0
1968	73.6	0.10	0.55	1.12	0.77	3.49	34.9
1969	71.4	0.10	0.46	1.12	0.77	2.83	28.3
1970	61.0	0.10	0.45	1.12	0.77	2.37	23.7
1971	58.5	0.15	0.45	1.12	0.77	3.41	34.1
1972	43.0	0.20	0.45	1.12	0.77	3.34	33.4
1973	41.0	0.15	0.45	1.12	0.77	2.39	23.9
1974	39.0	1.10	0.45	1.12	0.77	1.51	15.1
1975	9.0	0.05	0.45	1.75	0.37	0.13	1.3

*For 1975 base year, the values of C_i given in g/mi are listed in AP-42, Table D-1-5 under carbon monoxide, low altitude.

**In this example, all vehicles travel the same 4-mi (6.4 km) section of I-675. Therefore, the fraction of miles traveled by each model year equals the vehicle composition fraction. Otherwise, M_i would equal:

$$M_i = \frac{a_i b_i}{\sum_{i-n-12}^{n} a_i b_i}$$

where M_i = fraction of miles traveled during study period by i^{th} model year vehicles
a_i = fraction of i^{th} model year vehicles in use during study period
b_i = average number of miles driven by i^{th} model year vehicles during the study period
n = base year.

†Values for calculating V_i can be found in Table D1-23 under carbon monoxide. In this example, S = 40 mph (64 km/hr).

††Values for calculating Z_i can be found in Table D1-25 under carbon monoxide. Pre-1975 vehicles are assumed to be non-catalyst (without catalytic converter) and post-1974 vehicles are assumed to be catalyst (with catalytic converter).

‡r_i is calculated according to:

$$\text{pre-1975} \quad r_i = \frac{W + (100 - W)\,f(t)}{20 + 80\,f(t)}$$

$$\text{post-1974} \quad r_i = \frac{W + Xf(t) + (100 - W - X)\,g(t)}{20 + 27f(t) + 53g(t)}$$

where W = percentage of vehicles in cold start operation
X = percentage of vehicles in hot start operation
t = ambient temperature
f(t), g(t) = calculated according to formulas listed in Table D1-25 under carbon monoxide. Pre-1975 vehicles are assumed to be non-catalyst and post-1974 are assumed to be catalyst.

‡‡e_{ico}, the i^{th} model year contribution to the composite emission factor, is calculated according to:

$$e_{ico} = (C_i)\,(M_i)\,(V_i)\,(Z_i)\,(r_i)$$

#CO_i is the relative contribution of the i^{th} model year to the composite carbon monoxide emission from all vehicles during the rush period. It is calculated by

$$CO_i = \frac{e_{ico} \times 10{,}000 \text{ vehicle mi } (16\,000 \text{ km})}{1{,}000 \text{ g/kg}}$$

The carbon monoxide emissions resulting from the daily rush period are

$$(e_{CO})\ (10{,}000 \text{ vehicle mi } [16\,000 \text{ km}]) = 218{,}700 \text{ g}$$

$$= 218.7 \text{ kg}$$

Area Source Example

Problem

Calculate the emissions from a 250-acre (101-hectare) family housing area containing 1,000 duplex and single-family housing units. On an average winter day, each unit will use 500 cu ft (14 m^3) of natural gas.

Solution

Table 1.4-1 in AP-42, "Emission Factors for Natural Gas Combustion," supplies the emission factors to be used in the Domestic and Commercial Heating column.

$$\text{Total gas used in the area} = (1000 \text{ units})\ (500 \text{ cu ft } [14 \text{ m}^3]/\text{unit/day}) = 500{,}000 \text{ cu ft } (14\,000 \text{ m}^3) = 0.5 \times 10^6 \text{ cu ft/day}$$

Total emissions for the 250-acre (101-hectare) family housing area are as follows:

$$\text{Particulates} = (19 \text{ lb}/10^6 \text{ cu ft})(0.5 \times 10^6 \text{ cu ft/day}) = 9.5 \text{ lb/day } (4.31 \text{ kg/day})$$

$$\text{Sulfur oxides} = (0.6 \text{ lb}/10^6 \text{ cu ft})(0.5 \times 10^6 \text{ cu ft/day}) = 0.3 \text{ lb/day } (0.14 \text{ kg/day})$$

$$\text{Carbon monoxide} = (20 \text{ lb}/10^6 \text{ cu ft})(0.5 \times 10^6 \text{ cu ft/day}) = 10 \text{ lb/day } (4.54 \text{ kg/day})$$

$$\text{Hydrocarbons} = (9 \text{ lb}/10^6 \text{ cu ft})(9.5 \times 10^6 \text{ cu ft/day}) = 4 \text{ lb/day } (1.81 \text{ kg/day})$$

$$\text{Nitrogen oxides} = (80 \text{ lb}/10^6 \text{ cu ft})(0.5 \times 10^6 \text{ cu ft/day}) = 40 \text{ lb/day } (18.14 \text{ kg/day})$$

Table 2 shows the total emissions and emissions per acre for the area source example.

Table 2

Emissions for Area Source Example

Pollutant	Total Emissions, lb/day (kg/day)	Emissions, lb/acre/day (kg/hectare/day)
Particulates	9.5 (4.3)	0.0380 (.042)
Sulfur Oxides	0.3 (0.13)	0.0012 (.0012)
Carbon Monoxide	10 (4.5)	0.0400 (.044)
Hydrocarbons	4 (1.8)	0.0160 (.017)
Nitrogen Oxides	40 (18.1)	0.1600 (.178)

3 SOLID WASTE EMISSION FACTORS

General

This chapter provides factors for estimating the quantity and composition of solid waste materials generated by the operation of Army facilities (Tables 3 through 13). The factors are grouped by facility type with both average and 95 percent confidence interval values reported for each composition category and quantity estimation factor. The confidence interval encompasses the true average 95 percent of the time. A wide interval indicates a high degree of uncertainty in estimating the average.

It should be emphasized that these emission factors were developed from a broad base of information on similar civilian activities provided in the literature. Estimates generated using these factors may not be very accurate for a particular facility on a particular installation. This information should be used only as general guidance rather than as a substitute for a solid waste survey.

The following example illustrates the use of these emission factors.

Example

Problem

Estimate the amount of waste paper generated weekly by an administrative office building housing 150 employees.

Solution

Using the quantity estimation factors for offices as provided in Table 10, the amount of waste produced daily, Qd, is

Qd = (1.68 lb/employee/day) (150 employees)

Qd = 252 lb/day (114 kg/day)

The amount of waste produced weekly, Qw, is

Qw = (252 lb/day) (5 working days/week)

Qw = 1260 lb/week (571.5 kg/week)

From Table 10 it can be seen that 71.1 percent (by weight) of office wastes are paper. The amount of waste paper generated weekly, Pw, is

Pw = (0.711) (Qw)

Pw = (0.711) (1260 lb/week)

Pw = 806 lb/week (365.6 kg/week)

Emission Factors

Tables 3 through 13 present the emission factors for estimating the quantity and composition of solid waste materials. Each table also provides a description of the waste production and collection at the type of facility being considered.

Table 3

Barracks

Description

Most waste from barracks consists of paper, wood, cardboard, floor sweepings, cloth, metal cans, glass, and plastic. Waste collection within barracks confines depends on the duty schedule or inspection schedule. Waste disposal involves a common container for every one or two barracks, and collection is maintained on a scheduled basis.

The controlling waste generation factor is the number of barracks occupants. This number is affected by vacation/holiday leave schedules, changes in duty schedules, temporary duty (TDY) activities, field training activities, and changes in barracks occupants.

Waste Composition (% by weight]

Category	Average Value	95% Confidence Interval
Paper	49.3	(46.9 - 51.7)
Garbage	10.9	(6.9 - 14.9)
Metals	14.4	(10.4 - 18.4)
Glass	4.6	(3.5 - 5.7)
Yard waste	6.3	(5.1 - 8.5)
Plastics, rubber, and leather	5.2	(3.2 - 7.2)
Textiles	6.8	(5.3 - 7.3)
Wood	2.5	(1.2 - 3.8)
Miscellaneous*	1.5	(0.6 - 2.4)

*Includes ash, dirt, rock, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/day/resident	1.28	(0.42 - 2.13)
(kg/day/resident)	(0.58)	(0.19 - 0.97)

Table 4

Classrooms

Description

This category consists of training buildings and school buildings; its predominant waste material is scrap paper. Waste streams from high schools may contain significant amounts of wood and metal scraps if industrial arts classes are offered. Small amounts of glass, textiles, and plastics from training or packaging materials may also be found in the waste stream. Waste materials are generated each weekday during classroom activities and discarded in small containers. The containers are regularly emptied into a common container, the contents of which are periodically collected for disposal.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	74.2	(70.2 - 78.2)
Garbage	3.6	(3.0 - 4.2)
Metals	3.5	(3.1 - 3.9)
Glass	5.2	(1.0 - 9.4)
Yard waste	2.7	(1.3 - 4.1)
Plastic, rubber, and leather	4.4	(2.7 - 6.1)
Textiles	2.7	(1.5 - 3.9)
Wood	4.2	(2.6 - 5.8)
Miscellaneous*	2.6	(1.1 - 4.1)

*Includes ash, dirt, rocks, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/day/occupant	0.83	(0.76 - 0.89)
(kg/day/occupant)	(0.38)	(0.34 - 0.40)
lb/day/sq ft	0.0035	(0.0028 - 0.0042)
($kg/day/m^2$)	(0.0171)	(0.0137 - 0.0205)

Table 5

Clubs

Description

Clubs provide entertainment for personnel during off-duty hours. Typically, there are separate clubs for enlisted men, noncommissioned officers, and officers. Each club usually contains a bar and restaurant which produce the majority of waste materials. Waste is primarily produced during luncheon and dinner periods and during off-duty and special party activities. Waste is collected and placed in exterior storage containers following these periods. For sanitary reasons, these containers may be collected daily.

The controlling factor in determining the amount of waste produced is the number of persons served at the club. However, since most clubs have uncontrolled access, relating the amounts of waste produced to square footage may be preferable.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	50.2	(43.7 - 56.7)
Garbage	13.3	(6.4 - 20.2)
Metals	5.0	(2.2 - 7.3)
Glass	14.6	(11.0 - 18.2)
Yard waste	1.1	(0.5 - 1.7)
Plastic, rubber, and leather	6.4	(3.9 - 8.9)
Textiles	0.8	(0.1 - 1.5)
Wood	7.5	(4.9 - 10.1)
Miscellaneous*	0.6	(0.2 - 1.0)

*Includes ash, dirt, rocks, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/day/person served	2.02	(0.91 - 3.23)
(kg/day/person served)	(0.92)	(0.41 - 1.46)
lb/day/employee	5.9	(2.24 - 9.46)
(kg/day/employee)	(2.68)	(1.01 - 4.29)
lb/day/sq ft	0.03	(0.002 - 0.055)
($kg/day/m^2$)	(0.15)	(0.010 - 0.269)

Table 6

Commissaries

Description

Waste material generated by commissaries includes paper products, wood scraps, cardboard, plastic, floor sweepings, metal, glass, and some food wastes. Such wastes are collected at restocking periods and usually several times during regular business hours. To avoid using valuable storage space, waste is immediately placed in containers outside the building. More than one container may be required to handle all the generated waste. Due to sanitary regulations, containers are usually emptied daily. Among the most important factors controlling the amount of waste produced is the sales volume over a particular time period. Since waste generation occurs during restocking periods, and there is a considerable time lag between restocking and purchase of an item, correlating sales volume with waste production requires a sufficient time period.

Abnormal amounts of waste are produced during special sales and vacation/holiday leave periods.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	56.7	(45.7 - 66.7)
Garbage	16.5	(9.3 - 23.7)
Metals	2.5	(1.2 - 3.8)
Glass	T	—
Yard waste	T	—
Plastic, rubber, and leather	5.0	(3.8 - 6.2)
Textiles	1.1	(T - 2.2)
Wood	8.9	(5.3 - 12.5)
Miscellaneous*	T	—

*Includes ash, dirt, rocks, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/week/$ sales	0.18	(0.11 - 0.25)
(kg/week/$ sales)	(0.08)	(0.05 - 0.11)
lb/week/employee	91.7	(63.6 - 119.8)
(kg/week/employee)	(41.59)	(28.8 - 54.3)
lb/week/hour open	6.06	(4.7 - 7.4)
(kg/week/hour open)	(2.75)	(2.1 - 3.4)

Table 7

Family Housing

Description

Waste material generated in family housing areas consists primarily of newspaper, waste paper, metal containers, and glass containers. Housing without garbage grinders will also contribute a significant amount of garbage to the waste stream. Yard waste will make up a large portion of the waste stream following spring and fall cleanup and summer lawn cutting.

Collection of waste material depends on the types and amounts of material to be disposed. In areas where the combined refuse from several residences is deposited in a centrally located container, refuse collection may occur daily. Refuse collection from single-family residences and duplexes will probably occur twice weekly.

Factors which control waste composition and quantity include number of building occupants, season of the year, vacation/holiday periods, and changes in building occupancy.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	46.3	(42.9 - 49.7)
Garbage without grinder	20.1	(18.7 - 21.5)
Garbage with grinder	9.0	(7.1 - 10.9)
Metals	9.1	(8.4 - 9.8)
Glass	10.5	(9.4 - 11.6)
Yard waste—winter	4.0	(2.8 - 5.2)
Yard waste—other	15.0	(9.3 - 20.7)
Plastics, rubber, and leather	3.1	(2.5 - 3.7)
Textiles	2.7	(1.9 - 3.5)
Wood	1.6	(0.9 - 2.3)
Miscellaneous*	3.6	(2.2 - 5.0)

*Includes ash, dirt, rock, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/day/person	3.23	(2.77 - 3.69)
(kg/day/person)	(1.47)	(1.26 - 1.67)
lb/week/person	17.37	(12.46 - 22.28)
(kg/week/person)	(11.54)	(5.65 - 10.11)

Table 8

Hospitals

Description

Waste products from hospitals are derived from normal operation of the facilities and from administrative offices. Office waste is predominantly paper products with small amounts of plastic, wood, metal, and cloth. Collection of office waste, which is produced during normal working hours, is typically deferred until after business hours. Waste is collected either daily or every other day, and is then placed in a common container, the contents of which are periodically collected and disposed.

Other hospital waste includes combustible material, such as paper products, wood, cloth, rubber, plastic, floor sweepings, glass, and metals. Collection of these materials may warrant more frequent attention, but hospital disposal facilities are often capable of handling large volumes of such waste material.

Waste of human, animal, or pathogenic origin is typically incinerated on an as-generated basis.

The controlling waste production factors are the number of employees or patients occupying the facility. Changes in work force or patient load account for abnormal waste production. Such changes are caused by vacation/holiday leave periods, widespread contagious diseases, poor weather, and field exercises.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	68.2	(64.6 - 71.8)
Garbage	T	—
Metals	3.8	(2.2 - 5.4)
Glass	6.9	(4.2 - 9.6)
Yard waste	2.1	(1.0 - 3.2)
Plastic, rubber, and leather	10.9	(8.8 - 13.0)
Textiles	9.3	(4.2 - 14.4)
Wood	0.4	(0.1 - 0.7)
Miscellaneous*	1.4	(0.8 - 2.0)

*Includes ash, dirt, rocks, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/dey/patient	11.6	(9.6 - 13.6)
(kg/day/patient)	(5.26)	(4.4 - 6.2)
lb/day/bed	9.7	(8.1 - 11.2)
(kg/day/patient)	(4.40)	(3.7 - 5.1)
lb/week/bed (pathologic wastes only)	6.0	(0.96 - 11.02)
(kg/week/bed)	(2.72)	(0.44 - 5.00)

Table 9

Maintenance Facilities

Description

Waste materials generated at maintenance facilities, which house activities aimed at keeping Army equipment in good repair, consist of waste part packaging, spent parts, used rags, waste paper, petroleum, oil, and lubrication (POL) products, metal scraps, and wood scraps. Waste is produced during working hours, collected after hours by janitorial crews, and emptied into a container. The frequency of container collection depends on the type of maintenance performed and the level of activity.

The factors controlling the amount of waste material generated are the number of units serviced, the number of employees, and the size of the shop. The level of activity may vary according to preventive maintenance schedules for serviced equipment, season of the year, or intensity/duration of equipment use.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	45.6	(39.4 - 51.8)
Garbage	0.3	(0.1 - 0.5)
Metals	18.9	(14.2 - 23.6)
Glass	2.2	(0.6 - 3.8)
Yard waste	3.3	(1.9 - 4.7)
Plastic, rubber, and leather	6.8	(3.8 - 9.8)
Textiles	4.6	(2.6 - 6.6)
Wood	8.8	(5.2 - 12.4)
Miscellaneous*	6.0	(3.1 - 8.9)

*Includes ash, dirt, rocks, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/day/employee	6.51	(1.82 - 11.20)
(kg/day/employee)	(2.95)	(0.83 - 5.08)
lb/sq ft/day	0.0113	(0.0062 - 0.0164)
($kg/m^2/day$)	(0.0552)	(0.0303 - 0.0801)

Table 10

Offices

Description

Offices are involved in administration of base activities to insure fulfillment of the base mission. Waste from office areas consists predominantly of paper products, with small amounts of plastics, wood, metal, and cloth. Office waste is produced during normal working hours, but collection is typically deferred until after office hours. Waste is collected from office areas either daily or every other day, and emptied into a common container, the contents of which are periodically collected and disposed.

The controlling factors in waste production are the number of employees and the size of the office. Significant work force size changes can be caused by reorganization, contagious disease (cold, flu), vacation/holiday leave, poor weather, or TDY.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	71.1	(63.3 - 78.9)
Garbage	1.7	(0.4 - 3.0)
Metals	4.9	(3.3 - 6.5)
Glass	0.8	(0.4 - 1.2)
Yard waste	10.8	(7.1 - 14.5)
Plastic, rubber, and leather	4.6	(2.3 - 6.9)
Textiles	3.1	(1.5 - 4.7)
Wood	1.3	(0.1 - 2.5)
Miscellaneous*	1.5	(0.2 - 2.8)

*Includes ash, dirt, rocks, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/day/employee	1.68	(1.22 - 2.14)
(kg/day/employee)	(0.76)	(0.55 - 0.97)
lb/day/sq ft	0.0086	(0.0035 - 0.0137)
(kg/day/m²)	(0.0420)	(0.0171 - 0.0669)

Table 11

Post Exchanges

Description

Post exchanges provide goods and services to the installation population. Most of the solid waste comes from cardboard and other packaging materials such as plastic, wood, and metal. Business waste is primarily produced by restocking activities which normally take place after the establishment has closed or during off-peak hours. Waste materials are collected after restocking has been completed, and are emptied into a container for collection and disposal.

The factor controlling waste production is the amount of goods sold. Waste quantities can be estimated using sales volume, work force size, or business hours. Waste volumes may vary due to sales promotions, season of the year, or vacation/holiday periods.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	79.2	(73.7 - 84.7)
Garbage	2.3	(0.9 - 3.7)
Metals	4.4	(3.4 - 5.4)
Glass	T	—
Yard waste	6.2	(2.5 - 9.9)
Plastic, rubber, and leather	4.4	(2.6 - 6.2)
Textiles	2.0	(1.0 - 3.0)
Wood	3.1	(0.4 - 5.8)
Miscellaneous*	T	—

*Includes ash, dirt, rock, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/week/employee	20.2	(16.2 - 24.2)
(kg/week/employee)	(9.16)	(7.3 - 11.0)
lb/week/hour open	3.45	(2.05 - 4.85)
(kg/week/hour open)	(1.56)	(0.93 - 2.20)

Table 12

Cafeterias/Restaurants/Mess Halls

Description

Cafeterias/restaurants/mess halls prepare and serve food to the personnel quartered on the installation. Wastes consist of garbage and spent packaging materials such as cardboard, glass, metal, and paper. Wastes are produced during meal preparation and cleanup following meals. Wastes are usually collected and deposited in storage containers outside the facility (following meal preparation and after cleanup). These exterior storage containers are usually collected daily.

The factors controlling the quantity of waste produced are the number of meals served, the hours of operation, or the number of employees. Refuse quantities vary because of field training exercises, vacation/holiday periods, or TDY.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	58.0	(53.3 - 62.7)
Garbage	22.3	(18.1 - 26.5)
Metals	3.7	(2.9 - 4.5)
Glass	2.8	(1.4 - 4.2)
Yard waste	3.8	(1.8 - 5.8)
Plastic, rubber, and leather	3.9	(2.5 - 5.3)
Textiles	1.3	(0.6 - 2.0)
Wood	2.1	(1.4 - 2.8)
Miscellaneous*	1.3	(0.9 - 2.7)

*Includes ash, dirt, rocks, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/week/employee	30.11	(21.09 - 39.02)
(kg/week/employee)	(13.66)	(9.57 - 17.70)
lb/week/hour open	5.59	(2.64 - 8.54)
(kg/week/hour open)	(2.54)	(1.20 - 3.87)
lb/meal served	.95	(0.47 - 1.44)
(kg/meal served)	(0.43)	(0.21 - 0.65)

Table 13

Warehouses

Description

Warehouse facilities are used for packaging and storing material. Waste from storehouses and supply centers consists mainly of metal binding strips and spent packaging material such as wood scraps, cardboard, paper, and plastic dunnage. Storehouse wastes are produced by shipping and receiving activities which do not necessarily occur at regular intervals. Waste materials are collected during shipment processing and emptied into a container. The frequency of container collection depends on the level of activity in the storehouse.

Refuse quantities depend on the amount of material processed, the size of the warehouse, or the size of the work force.

Waste Composition (% by weight)

Category	Average Value	95% Confidence Interval
Paper	44.2	(36.6 - 51.8)
Garbage	0.8	(0.2 - 1.4)
Metals	2.5	(1.8 - 3.2)
Glass	1.0	(0.4 - 1.6)
Yard waste	0.6	(0.2 - 1.0)
Plastic, rubber, and leather	3.0	(1.8 - 4.2)
Textiles	2.5	(1.4 - 3.6)
Wood	52.8	(45.3 - 60.3)
Miscellaneous*	4.9	(2.5 - 7.3)

*Includes ash, dirt, rocks, and nondistinguishable wastes.

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
lb/day/employee	11.8	(3.74 - 19.92)
(kg/day/employee)	(26.01)	(1.70 - 9.04)
lb/day/sq ft	0.0074	(0.0008 - 0.014)
(kg/day/m²)	(0.0361)	(0.0039 - 0.684)

4 WASTEWATER EMISSION FACTORS

General

This chapter contains literature-based emission factors for estimating the composition and quantity of wastewater discharged by the operation of Army facilities (Tables 14 through 24). The factors are grouped by facility type, with average and 95 percent confidence interval values reported for most composition category and quantity emission factors. The 95 percent confidence interval contains the average parameter value 95 percent of the time. The range indicates the variation in data encountered in the literature; a wider interval or range is an indication of a high degree of uncertainty in the estimate of the average.

Because these factors were developed using literature data on a group of similar civilian activities, the estimates may not be accurate for a specific situation. It should be emphasized that these estimates should be used only for general guidance and should not be a substitute for a wastewater survey.

The following example illustrates the use of these factors.

Example

Problem

Estimate the daily 5-day biochemical oxygen demand (BOD_5) load coming from a hospital containing 200 patients and staff.

Solution

Using Table 19, the quantity of wastewater produced daily, Qd, is

$$Qd = (125 \text{ gal/capita/day})(200 \text{ patients})$$

$$Qd = 25{,}000 \text{ gal/day } (94\,625 \, \ell/\text{day})$$

Table 24 indicates that the average BOD_5 level for hospital wastewater is 303 mg/ℓ. The total BOD_5 load is therefore

$$\text{Total } BOD_5 = \frac{(303 \text{ mg}/\ell)(3.785 \, \ell/\text{gal})(25{,}000 \text{ gal/day})}{(4.54 \times 10^5 \text{ mg/lb})}$$

$$\text{Total } BOD_5 = 63 \text{ lb/day } (28.6 \text{ kg/day})$$

Emission Factors

Tables 14 through 24 present the emission factors for estimating the quantity and composition of wastewater. Each table also provides a description of the wastewater production and collection at the type of facility being considered.

Table 14

Auto Washracks

Description

Most wastewater produced by auto washracks is produced by vehicle washing, which introduces detergents, waxes, grease, oils, and dirt into the wastewater. The amount of wastewater produced by washracks is a direct function of the number of autos washed, which varies according to season, day of the week, weather conditions, vacation/holiday leave periods, and large field training exercises.

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
Total suspended solids (TSS), mg/ℓ	300	(202 - 398)
Total volatile solids (TVS), mg/ℓ	1229	(430 - 2028)
Total volatile suspended solids (TVSS), mg/ℓ	72	(62 - 82)
Total solids (TS), mg/ℓ	2044	(1457 - 2631)
Turbidity, JTU	124	(100 - 148)
Total organic carbon (TOC), mg/ℓ	348	(139 - 557)
Chemical oxygen demand (COD), mg/ℓ	933	(442 - 1424)
BOD_5, mg/ℓ	60	(42 - 77)
Total phosphorus, mg/ℓ	33	(31 - 35)
Total Kjeldahl nitrogen (TKN), mg/ℓ	3.4	(2.3 - 4.5)
Detergents, mg/ℓ	108	(39 - 177)
Alkalinity, mg/ℓ	287	(167 - 407)
pH	9.0	(8.4 - 9.6)
Metals:		
Lead (Pb), mg/ℓ	2.5	(1.2 - 3.8)
Copper (Cu), mg/ℓ	0.35	(0.13 - 0.57)
Nickel (Ni), mg/ℓ	0.32	(0.15 - 0.49)
Cadmium (Cd), mg/ℓ	0.11	(0.01 - 0.21)
Zinc (Zn), mg/ℓ	2.9	(1.2 - 4.6)
Chromium (Cr), mg/ℓ	0.39	(0.12 - 0.66)
Aluminum (Al), mg/ℓ	0.80	(0.71 - 0.89)
Iron (Fe), mg/ℓ	4.7	(3.1 - 6.3)
Magnesium (Mg), mg/ℓ	15	(13 - 17)
Calcium (Ca), mg/ℓ	31	(20 - 42)

Quantity Estimation Factor

Units	Average Value
gal/car washed	44.9
(ℓ/car washed)	(169.9)

Table 15

Bakeries

Description

Wastewater from bakery facilities is produced primarily by washing equipment and ingredient storage containers, which introduces food particles, greases, and detergents or other cleaning compounds into the wastewater. The amount of washing wastewater produced depends on the quantity of goods baked. The quantity of baked goods produced varies by season, day of the week, vacation/holiday leave period, and field training activities.

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
pH	7.2	(4.7 - 9.7)
COD, mg/ℓ	5914	(2504 - 9324)
BOD_5, mg/ℓ	3539	(1784 - 5294)
TS, mg/ℓ	5669	(2780 - 8558)

Quantity Estimation Factor

Units	Average Value
gal/lb baked goods	0.97
(ℓ/kg baked goods)	(8.09)

Table 16

Boiler Plants

Description

Wastewater generators typically found in boiler plants consist of condensate cooling systems, boiler feedwater treatment systems, boiler systems, maintenance cleaning, ash handling systems, and sanitary systems.

The principal condensate cooling system in use today is the cooling tower which is normally used with any large air-conditioning or heat-transfer operation. There are two types of cooling towers: single-pass and high-efficiency recycling towers. A single-pass system uses water from a surface or groundwater source which is pumped, heated, cooled by evaporation, and discharged to surface or groundwater. A recycling system repeatedly cools and reuses water. Water is added to this system to replace evaporative loss and to maintain a fixed dissolved solids concentration. If the dissolved solids concentration exceeds the maximum limit, a portion of the system's water must be discharged in a blowdown operation. The frequency and amount of blowdown (Table 16a) depend on the maximum dissolved solids concentration of added water, and the evaporation rate of the recycled water.

There are several boiler feedwater treatment systems in use today. Clarification and softening systems, which use chemical precipitation, produce a chemical sludge which must be removed. Typically, this sludge is spread out in beds and allowed to air dry. With filtration systems, backwashes are needed to remove collected solids from the filter medium, thus producing backwash water as wastewater. Ion exchange systems produce acidic and caustic regeneration solutions as wastewater. These solutions are rinsed through the ion exchange whenever their exchange capacity has been depleted. Evaporator systems produce periodic blowdown as wastewater (Table 16b) because a portion of the boiling evaporation pool is removed as blowdown and replaced with raw water with lower mineral salt content to inhibit mineral salts from crystallizing on the heating tube surfaces.

Boiler operation also produces periodic blowdown as wastewater (Table 16c). Contaminated water is discharged from boiler systems when the boiler system water exceeds a predetermined total dissolved solids (TDS) concentration. The TDS concentration is maintained at a normal operating level when highly concentrated boiler water is flushed from the boiler system and replaced with fresh water. This process reduces the amount of dissolved minerals which crystallize on heating surfaces.

The amount of blowdown is directly controlled by the TDS concentration of the individual boiler system. Blowdown frequency is controlled by the TDS concentration of the fresh water supply and the evaporative losses in the boiler system.

Maintenance cleaning wastewaters include both periodic equipment cleaning and routine general area cleaning. Boiler tube (Table 16d), air preheater (Table 16e), and cooling tower cleaning usually occur every 1 or 2 years, depending on the amount of heat transfer surface sealing. Routine area cleanup occurs once or twice a week, depending on the type of fossil fuel burned. Wastewater contaminants depend on the type of cleaning performed and the type of cleaning solution used.

Ash handling systems which use a water slurry to remove bottom ash produce ash pond overflow as wastewater. In a slurry ash handling system, the bottom ash-water slurry is placed in a lagoon where the bottom ash particles are allowed to settle out. Typically, as bottom ash slurry is introduced at one end of the lagoon, an equal amount is removed as overflow at the other end (Table 16f).

Sanitary wastes are produced by restroom and shower use. The sanitary wastewater contribution can be evaluated using the toilet and bath/shower estimation factors listed in the residential category (Tables 24b and d).

Table 16a

Cooling Tower Blowdown

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
Alkalinity, mg/ℓ	82	(45 - 119)
BOD_5, mg/ℓ	6.6	(4.2 - 9.0)
COD, mg/ℓ	34.9	(12.0 - 57.8)
TS, mg/ℓ	3741	(1243 - 6239)
TDS, mg/ℓ	928	(604 - 1252)
TSS, mg/ℓ	27	(13 - 41)
Phosphorus, mg/ℓ	2.05	(0.87 - 3.23)
Hardness as calcium carbonate ($CaCO_3$), mg/ℓ	853	(488 - 1218)
Sulfate, mg/ℓ	383	(218 - 548)
Chloride, mg/ℓ	30.6	(17.1 - 44.1)
Cr, mg/ℓ	0.05	(0.032 - 0.068)
Fe, mg/ℓ	0.64	(0.27 - 1.01)
pH	7.4	(6.8 - 8.0)

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
m^3/mW/day	1.23	(0.49 - 1.97)
gal/min	45	(23 - 67)
(ℓ/min)	(170)	(87 - 254)

Table 16b

Evaporator Blowdown

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
Alkalinity, mg/ℓ	69.8	(36.0 - 103.6)
BOD_5, mg/ℓ	4.45	(2.31 - 6.59)
COD, mg/ℓ	75.0	(67.8 - 82.2)
TS, mg/ℓ	344	(169 - 519)
TDS, mg/ℓ	372	(187 - 557)
TSS, mg/ℓ	41	(7 - 75)
Sulfate, mg/ℓ	46	(2 - 90)
Iron, mg/ℓ	1.07	(0.14 - 2.00)

Quantity Estimation Factor

Units	Average Value	95% Confidence Interval
m^3/mW/day	0.0532	(0.0156 - 0.0908)

Table 16c

Boiler Blowdown

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
COD, mg/ℓ	9.0	(4.9 - 13.1)
TS, mg/ℓ	530	(160 - 900)
TDS, mg/ℓ	305	(141 - 469)
TSS, mg/ℓ	9.5	(4.3 - 14.7)
Alkalinity, mg/ℓ	71	(26 - 116)
Hardness as $CaCO_3$, mg/ℓ	20.1	(8.2 - 32.0)

Quantity Estimation Factor

Units	Average Value	95% Confidence Interval
gal/min/(10^6 lb steam/hr)	93	(69 - 117)
(ℓ/min/[10^6 kg steam/hr])	(776)	(576 - 976)
m^3/mW/day	0.197	(0.102 - 0.292)

Table 16d

Boiler Tube Cleaning

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
Cr, mg/ℓ	3.2	(0.6 - 5.8)
Ni, mg/ℓ	77.0	(70.3 - 83.7)
Zn, mg/ℓ	35.8	(20.1 - 51.5)
Fe, mg/ℓ	438	(429 - 447)
COD, mg/ℓ	1898	(865 - 2931)
Cu, mg/ℓ	198	(184 - 212)
TSS, mg/ℓ	135	(112 - 158)
TDS, mg/ℓ	3590	(551 - 6629)
TS, mg/ℓ	5060	(1029 - 9091)

Quantity Estimation Factor

Units	Average Value	95% Confidence Interval
gal/cleaning/(10^6 lb steam/hr)	106,000	—
(ℓ/cleaning/[10^6 kg steam/hr])	(884,500)	—
m^3/mW/cleaning	1.47	(1.17 - 1.77)

Table 16e

Air Preheater Cleaning

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
BOD_5, mg/ℓ	5.3	(4.0 - 6.6)
COD, mg/ℓ	19.5	(15.2 - 23.8)
TS, mg/ℓ	13292	(13203 - 13381)
TDS, mg/ℓ	8859	(8820 - 8898)
TSS, mg/ℓ	2178	(2158 - 2198)
Nitrogen, ammonia (NH_3-N), mg/ℓ	2.56	(2.46 - 2.66)
Nitrogen, nitrate (NO_3-N), mg/ℓ	2.47	(1.51 - 3.43)
Phosphorus, mg/ℓ	1.12	(0.68 - 1.56)
Turbidity, JTU	491	(484 - 498)
Hardness as $CaCO_3$, mg/ℓ	4420	(4396 - 4444)
Sulfate, mg/ℓ	1190	(1178 - 1202)
Cr, mg/ℓ	6.04	(1.49 - 10.59)
Cu, mg/ℓ	4.97	(4.94 - 5.00)
Fe, mg/ℓ	1700	(1699 - 1701)
Mg, mg/ℓ	983	(972 - 994)
Zn, mg/ℓ	4.91	(4.85 - 4.97)
Ni, mg/ℓ	67	(57 - 77)

Quantity Estimation Factor

Units	Average Value	95% Confidence Interval
m^3/mW/cleaning	0.306	(0.09 - 0.53)

Table 16f

Ash Pond Overflow

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
Alkalinity, mg/ℓ	121	(99 - 143)
BOD_5, mg/ℓ	6.3	(3.9 - 8.7)
COD, mg/ℓ	23.4	(17.0 - 29.8)
TS, mg/ℓ	673	(518 - 828)
TDS, mg/ℓ	522	(419 - 625)
TSS, mg/ℓ	44.3	(34.2 - 54.4)
Turbidity, JTU	22	(16 - 27)
Hardness as $CaCO_3$, mg/ℓ	314	(249 - 379)
Sulfate, mg/ℓ	250	(208 - 292)
Fe, mg/ℓ	0.84	(0.46 - 1.22)
Mg, mg/ℓ	0.21	(0.09 - 0.33)

Quantity Estimation Factor

Units	Average Value	95% Confidence Interval
m^3/mW/day	21.2	(15.8 - 26.6)

Table 17

Community, Commercial, and Institutional Facilities

Description

This category includes all educational facilities for both dependents and installation personnel, all community facilities (e.g., auditoriums, gyms, recreation facilities), administrative/office facilities, protective facilities (e.g., police or fire stations), and commercial facilities (e.g., bowling centers, post exchanges). Most wastewater emanating from these facilities comes from restroom use and routine cleanup. The quantity of wastewater produced depends on the number of people using the facility. Office and educational facilities produce most of their wastewater during the 5-day work week. Community facilities produce wastewater at irregular intervals, depending on their usage. Protective facilities produce wastewater 24 hours/day and 7 days/week. Commercial facilities produce wastewater during hours of operation, which vary by type of facility.

Wastewater Composition

The composition of restroom wastewater can be approximated by using the emission factors listed for toilet and bath/shower usage in Tables 24b and d.

Quantity Estimation Factors

Facility	Average Value
Elementary school	10 gal/capita/day (37.8ℓ/capita/day)
Elementary school (with cafeteria)	20 gal/capita/day (75.7ℓ/capita/day)
High school (with showers)	15 gal/capita/day (56.8ℓ/capita/day)
High school (with showers and cafeteria)	20 gal/capita/day (75.7ℓ/capita/day)
Office	15 gal/capita/day (56.8 ℓ/capita/day)
Places of public assembly	3 gal/capita/day (11.4 ℓ/capita/day)
Stores	400 gal/restroom/day (1514ℓ/restroom/day

Table 18

Ready-Mix Concrete Production

Description

Wastewater from concrete production originates primarily from equipment washing, aggregate washing, wet dust collectors, and excess mix water. In aggregate production and concrete batch plants, water sprays are used to control dust and clean crushing and hauling equipment. Wastewater flow from restroom and shower use in permanent production facilities can be estimated using factors for toilet and bath/shower use listed in the residential category (Tables 24b and d).

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
	Truck Mix	
pH	11.6	(11.5 - 11.7)
TS mg/ℓ		
with recycling	2775	(2359 - 3191)
without recycling	1375	(1147 - 1603)
SS, mg/ℓ	171	(137 - 205)
	Central Mix	
pH	11.9	(11.8 - 12.0)
TS, mg/ℓ		
without recycling	1457	(1193 - 1721)
with recycling	2803	(2445 - 3161)
SS, mg/ℓ	88	(45 - 132)

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
Total wastewater flow		
gal/truck/day	182	(154 - 210)
(ℓ/truck/day	(689)	(583 - 795)
Truck washout		
gal/cu yd/day	11.5	(9.8 - 13.2)
(ℓ/m³/day)	(56.9)	(48.5 - 65.3)
Truck washoff		
gal/wash	31.8	(28.7 - 34.9)
(ℓ/wash)	(120.4)	(108.6 - 132.1)
Central mix washout		
gal/wash	455	(393 - 517)
(ℓ/wash)	(1722)	(1488 - 1957)
gal/cu yd	10.2	(7.5 - 12.9)
(ℓ/m³)	(50.5)	(37.1 - 63.9)

Table 19

Hospitals

Description

Wastewater from hospitals comes primarily from patients' bath/shower and toilet use, kitchen activities, laundry activities, laboratory activities, general area cleanup, and heating/cooling plants. Wastewater volume is primarily a function of patient load. Factors for toilet and bath/shower use, mess halls, industrial laundries, and boiler plants can be used to analyze similar hospital activities.

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
TSS, mg/ℓ	193	(156 - 230)
VSS, mg/ℓ	193	(169 - 217)
TDS, mg/ℓ	1407	(1171 - 1643)
COD, mg/ℓ	833	(725 - 941)
BOD_5, mg/ℓ	253	(226 - 280)
Grease and oil, mg/ℓ	45	(40 - 50)
Turbidity, JTU	50	(44 - 56)
Sulfate, mg/ℓ	34	(21 - 47)
Phosphate (as P), mg/ℓ	169	(141 - 197)
pH	7.6	(7.4 - 7.8)
Alkalinity, mg/ℓ	122	(94 - 150)
ABS (measure of detergents), mg/ℓ	75	(69 - 81)
Metals:		
Cd, mg/ℓ	0.02	(0.015 - 0.025)
Ca, mg/ℓ	15	(12 - 18)
Cr, mg/ℓ	1.07	(0.94 - 1.20)
Fe, mg/ℓ	0.33	(0.29 - 0.37)
Pb, mg/ℓ	0.33	(0.28 - 0.38)
Mg, mg/ℓ	16	(14 - 18)
Potassium (K), mg/ℓ	34	(33 - 35)
Na, mg/ℓ	361	(347 - 375)
Silver (Ag), mg/ℓ	0.27	(0.22 - 0.32)

Quantity Estimation Factors

Units	Average Value	95% Confidence Interval
gal/capita/day	125	(94 - 150)
(ℓ/capita/day)	(473)	(356 - 568)
gal/bed/day	285	(198 - 342)
(ℓ/bed/day)	(1079)	(749 - 1294)

Table 20

Industrial Laundry Facilities

Description

Wastewater from laundry facilities is generated primarily by washing clothes, which introduces grease, oil, and dirt removed from clothing, and soap, detergents, bleach, brighteners, and other agents used in the cleaning process into the wastewater. Wastewater quantities are a function of the amount of material washed. Significant variations in flow may occur due to vacation/holiday periods or extensive field training exercises. Contribution of restroom and shower use to the total wastewater flow can be assessed using toilet and bath/shower factors listed in the residential category (Tables 24b and d).

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
pH	10.5	(10.3 - 10.7)
Grease and oils, mg/ℓ	1831	(1219 - 2443)
TOC, mg/ℓ	941	(651 - 1231)
BOD_5, mg/ℓ	631	(375 - 887)
TS, mg/ℓ	6860	(6337 - 7383)
TSS, mg/ℓ	934	(617 - 1251)
VSS, mg/ℓ	1734	(1612 - 1856)
TDS, mg/ℓ	4579	(3871 - 5287)
TVS, mg/ℓ	3939	(3517 - 4361)
Metals:		
Silicon (Si), mg/ℓ	129	(79 - 179)
Ca, mg/ℓ	739	(682 - 796)
Mg, mg/ℓ	6.4	(3.7 - 9.1)
Cu, mg/ℓ	2.6	(1.6 - 3.6)
Pb, mg/ℓ	14.0	(9.1 - 18.9)
Cd, mg/ℓ	0.34	(0.24 - 0.44)
Zn, mg/ℓ	4.2	(2.4 - 6.0)
Fe, mg/ℓ	0.34	(0.09 - 0.59)
Cr, mg/ℓ	1.5	(0.9 - 2.1)
Ni, mg/ℓ	0.89	(0.40 - 1.38)

Quantity Estimation Factor

Units	Average Value
gal/lb clothes washed	5.6
(ℓ/kg clothes washed)	(46.7)

Table 21

Laundromats

Description

Laundromat wastewater primarily comes from use of coin-operated washing machines. Pollutants introduced to the wastewater include dirt, grease, and oil removed from the laundered material and cleaning and bleaching agents. The quantity of wastewater produced is a function of the frequency of machine use. Because laundromats are typically always open, wastewater is generated 24 hours/day, 7 days/week. Variations in wastewater flow occur due to vacation/holiday periods, weather conditions, day of the week, season of the year, and field training exercises.

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
pH	8.2	(7.8 - 8.6)
BOD_5, mg/ℓ	191	(99 - 283)
COD, mg/ℓ	369	(281 - 457)
TS, mg/ℓ	840	(594 - 1086)
TSS, mg/ℓ	114	(87 - 141)
VSS, mg/ℓ	42.7	(31.5 - 53.9)
TDS, mg/ℓ	359	(257 - 461)
Methylene blue active substance (MBAS), mg/ℓ	57	(46 - 68)
Turbidity, JTU	246	(209 - 283)
Hexane solubles, mg/ℓ	32.2	(18.0 - 46.4)
Phosphate (as P), mg/ℓ	213	(140 - 280)

Quantity Estimation Factor

Units	Average Value	95% Confidence Interval
gal/wash/machine	39	(35 - 44)
(ℓ/wash/machine)	(148)	(132 - 167)

Table 22

Cafeterias/Restaurants/Mess Halls (Without Garbage)

Description

Wastewater from cafeterias, restaurants, and mess halls comes primarily from cleaning equipment, storage containers, and work area, as well as general area cleanup. Wastewater quantities are a function of the number of meals served. Variations in flow occur due to vacation/holiday periods, field training exercises, season of the year, and day of the week.

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
Alkalinity, mg/ℓ	145	(127 - 163)
TOC, mg/ℓ	175	(91 - 259)
Turbidity, JTU	62	(44 - 79)
pH	6.5	(6.3 - 6.7)
COD, mg/ℓ	2800	—
TS, mg/ℓ	3552	—
TSS, mg/ℓ	2498	—
TDS, mg/ℓ	323	(280 - 366)
Total phosphate, mg/ℓ	54.5	(32.3 - 76.7)
Oil and grease, mg/ℓ	878	—
MBAS, mg/ℓ	8.4	(8.3 - 8.5)
Sulfate, mg/ℓ	21.5	(8.8 - 34.2)
Hardness as $CaCO_3$, mg/ℓ	33.3	(22.1 - 44.5)

Quantity Estimation Factor

Units	Average Value
gal/meal	3
(ℓ/meal)	(11.4)

Table 23

Photographic Laboratories

Description

Wastewater from photographic laboratories is generated by photographic film or plate processing and by restroom facilities. Washwater and rinsewater remove substantial amounts of developing liquid and chemicals used in the developing baths. These chemicals are toxic to plant and animal life. Continual disposal of spent chemical baths or use of flow-through chemical baths increases the toxic concentrations of the effluent. Photo lab effluents contain large amounts of chemical-reducing contaminants, which tend to exert a high chlorine demand on wastewater or water treatment plants. Wastewater contributions of restroom use can be assessed by using the factor for toilet use listed in the residential category (Table 24d).

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
pH	7.8	(7.3 - 8.3)
BOD_5, mg/ℓ	292	(123 - 461)
COD, mg/ℓ	505	(495 - 515)
TS, mg/ℓ	2035	(1905 - 2165)
TSS, mg/ℓ	233	(149 - 317)
TDS, mg/ℓ	2880	(1998 - 3762)

Table 24

Residences

Description

Wastewater from family housing areas is produced by dishwashing, toilet use, bath/shower use, clothes laundering, and garbage grinding. Wastewater from troop housing is produced by toilet use, bath/shower use, and general area cleanup. In both situations, personal hygiene is the principal source of wastewater. Table 24a presents the factors for the composite residential wastewater, and Tables 24b through 24e present the factors for wastewater from individual residential sources.

Table 24a

Residential Composite Wastewater

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
pH	7.2	(7.17 - 7.23)
BOD_5, mg/ℓ	168	(149 - 187)
TOC, mg/ℓ	195	(148 - 242)
TS, mg/ℓ	461	(445 - 476)
TSS, mg/ℓ	146	(138 - 154)
Chlorides, mg/ℓ	34	(33 - 35)
Mg, mg/ℓ	6.5	(4.4 - 8.6)

Quantity Estimation Factors

	Units	Average Values
Trailer Courts	gal/person/day	50
	(ℓ/person/day)	(189)
Residences	gal/person/day	75
	(ℓ/person/day	(284)

Table 24b

Bath/Shower Wastewater

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
pH	7.2	(7.1 - 7.3)
BOD_5, mg/ℓ	174	(124 - 224)
TOC, mg/ℓ	40	(13 - 68)
TS, mg/ℓ	345	(285 - 405)
TSS, mg/ℓ	115	(109 - 121)
Chlorides, mg/ℓ	21.5	(17.9 - 25.1)
Sulfates, mg/ℓ	34	(23 - 45)
Phosphates (PO_4), mg/ℓ	0.20	(0.10 - 0.30)
NH_3-N, mg/ℓ	1.14	(0.92 - 1.36)
MBAS, mg/ℓ	0.15	(0.07 - 0.23)
Turbidity, JTU	111	(84 - 138)
Phenols, mg/ℓ	0.073	(0.062 - 0.084)
Metals:		
Fe, mg/ℓ	0.29	(0.22 - 0.36)
Sodium (Na), mg/ℓ	11.7	(8.9 - 14.5)
K, mg/ℓ	2.44	(1.92 - 2.96)
Mg, mg/ℓ	2.46	(2.20 - 2.72)
Ca, mg/ℓ	15	(13 - 17)

Quantity Estimation Factor

Units	Average Value	95% Confidence Interval
gal/use	20	(10 - 30)
(ℓ/use)	(76)	(38 - 114)

Table 24c

Domestic Laundry Wastewater

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
pH	7.6	(7.4 - 7.8)
BOD$_5$, mg/ℓ	311	(211 - 411)
TOC, mg/ℓ	145	(99 - 191)
TS, mg/ℓ	1015	(740 - 1290)
TSS, mg/ℓ	200	(98 - 302)
MBAS, mg/ℓ	92	(59 - 125)
Total phosphate, mg/ℓ	332	(252 - 412)
Chlorides, mg/ℓ	96	(68 - 124)
Sulfates, mg/ℓ	147	(101 - 193)
NO_3-N, mg/ℓ	1.28	(0.86 - 1.70)
NH_3-N, mg/ℓ	2.93	(1.75 - 4.11)
Turbidity, JTU	49	(31 - 67)
Metals:		
Fe, mg/ℓ	0.37	(0.30 - 0.44)
Cd, mg/ℓ	0.018	(0.004 - 0.032)
Cr, mg/ℓ	0.035	(0.019 - 0.051)
Mercury (Hg), mg/ℓ	0.23	(0.17 - 0.27)
Na, mg/ℓ	135	(97 - 172)
K, mg/ℓ	4.55	(3.08 - 6.02)
Mg, mg/ℓ	4.90	(3.23 - 6.57)
Ca, mg/ℓ	30	(25 - 35)

Quantity Estimation Factor

Units	Average Value
gal/use	40
(ℓ/use)	(151)

Table 24d

Toilet Wastewater

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
BOD$_5$, mg/ℓ	177	(142 - 212)
TS, mg/ℓ	729	(551 - 907)
TSS, mg/ℓ	422	(353 - 491)
TKN, mg/ℓ	121	(64 - 178)
Total phosphorus, mg/ℓ	12.9	(8.9 - 16.9)

Quantity Estimation Factor

Units	Average Value	95% Confidence Interval
gal/toilet use	5	(4 - 6)
(ℓ/toilet use)	(19)	(15 - 23)

Table 24e

Dishwashing Wastewater

Wastewater Composition

Parameter	Average Value	95% Confidence Interval
pH	6.6	(6.1 - 7.1)
BOD$_5$, mg/ℓ	445	(68 - 1027)
TS, mg/ℓ	753	(257 - 1712)
TSS, mg/ℓ	223	(34 - 633)
Sulfates, mg/ℓ	28.8	(14.6 - 43.0)

Quantity Estimation Factor

Units	Average Value
gal/use	7
(ℓ/use)	(26)

5 RECOMMENDATIONS

The emission factors contained in this report should be used whenever a rough estimate of pollutant discharges from a certain activity is required. Emission factor estimates can be used to assess the environmental consequences of proposed actions and to approximate the magnitude of problems for preliminary planning. It should be noted, however, that estimates made by the emission factor approach may or may not be accurate for a specific situation. These estimates should not be used as a substitute for field data when designing specific pollution control measures or evaluating specific problem situations.